

# **Reliability Study Update**

## **High Pressure Safety Injection**

**1987–2002**

This report presents a performance evaluation of the High Pressure Safety Injection (HPI) system at 69 United States commercial pressurized-water reactors (PWRs). The evaluation is based on the operating experience from 1987 through 2002, from 74 PWRs, as reported in Licensee Event Reports (LERs). This is the latest update to NUREG/CR 5500 Volume 9.

This report calculates two basic models for the HPI system. The first model, failure to start (FTS), models the HPI system start and injection. The second model, 8-hour mission, models the HPI system start, injection, and pump run for 8 hours. See the HPI Fault Tree Description document for more detail.

The HPI system has been categorized into six groups. The groupings are based on the number of injection points (as measured by the number of steam generators (SGs) or the number of cold legs), the number of high-head safety injection (HHSI) pumps, and the number of intermediate-head safety injection pumps (IHSI). [Table 1](#) summarizes those groups. Information that is more detailed can be found in Section [5](#)

**Table 1. HPI design class summary.**

| HPI Design Class              | Number of Plants | HPI Design Class            | Number of Plants |
|-------------------------------|------------------|-----------------------------|------------------|
| 1 — (2 HHSI or 2 IHSI; 2 SGs) | 19               | 4 — (4 IHSI; 3 SGs)         | 2                |
| 2 — (3 HHSI or 3 IHSI; 2 SGs) | 8                | 5 — (3 IHSI; 4 SGs)         | 4                |
| 3 — (2 HHSI or 2 IHSI; 3 SGs) | 12               | 6 — (2 HHSI, 2 IHSI; 4 SGs) | 29               |

## **1 LATEST VALUES AND TRENDS**

### **1.1 Industry-Wide Unavailability and Unreliability**

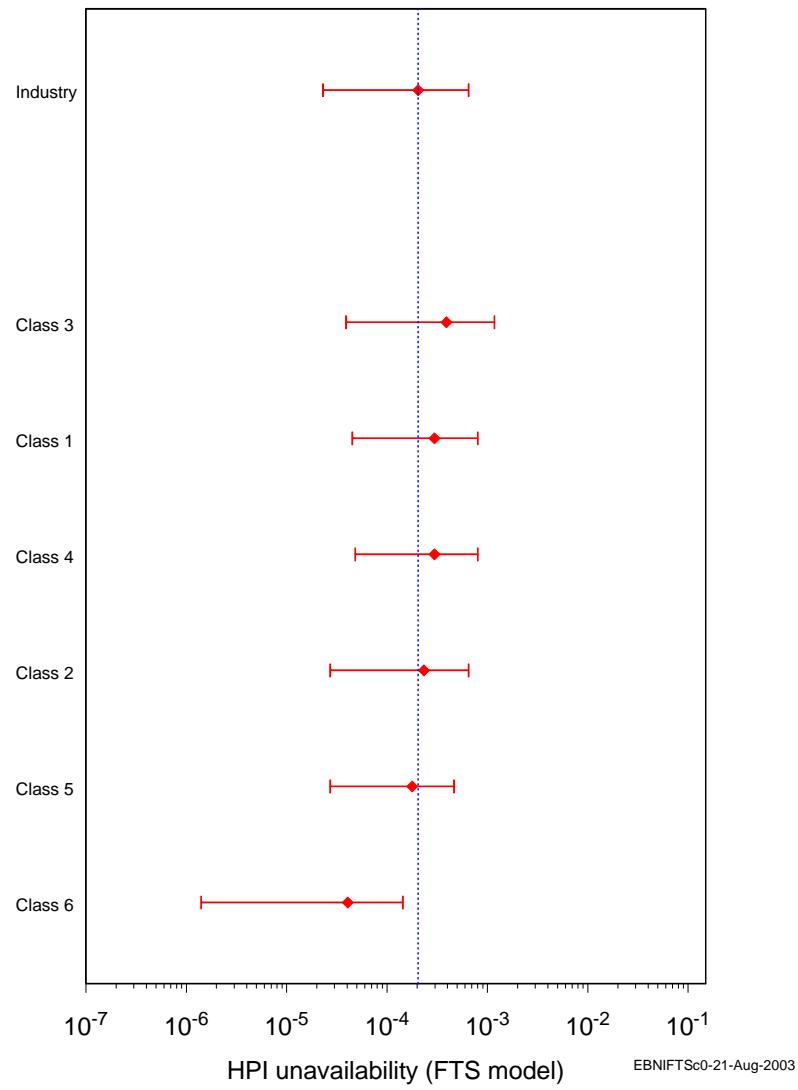
The industry-wide unavailability and unreliability of the HPI system have been estimated from operating experience. A failure to start (FTS) unavailability and an 8-hour mission unreliability were evaluated, see [Table 2](#). The estimates are based on failures that occurred during unplanned demands, and cyclic and quarterly surveillance tests.

**Table 2. Industry-wide values.**

| Model                             | Lower (5%) | Mean     | Upper (95%) |
|-----------------------------------|------------|----------|-------------|
| Failure-to-Start (Unavailability) | 2.25E-05   | 2.04E-04 | 5.79E-03    |
| 8-hour Mission (Unreliability)    | 4.50E-05   | 1.52E-03 | 1.11E-01    |

## 1.2 Fail to Start Model Results

The unavailability of the HPI system for each design class has been calculated from the operating experience for the failure to start (FTS) mission. The waterfall plot is shown in [Figure 1](#) and the data table is shown in [Table 3](#). The 1987–2002 HPI operational experience includes zero total system failures and three HPI segment failures. Due to the sparseness of the data, between-plant variation of failure probabilities would not be meaningful.

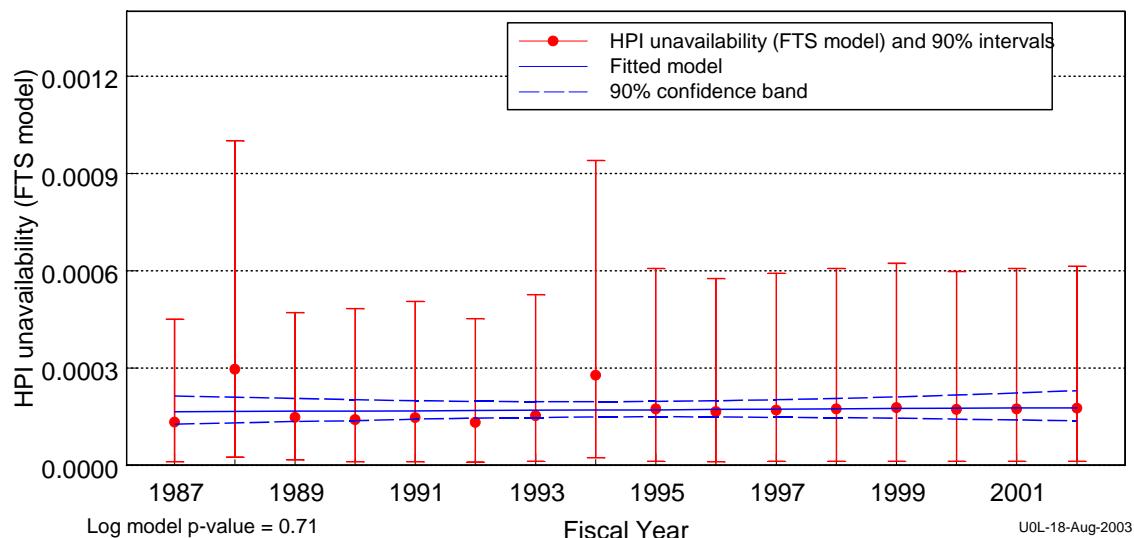


**Figure 1. HPI design class unavailability (FTS model).**

**Table 3. HPI unavailability (start only model) by design class.**

| Design Class | Lower (5%) | Mean     | Upper (95%) |
|--------------|------------|----------|-------------|
| Industry     | 2.25E-05   | 2.04E-04 | 6.49E-04    |
| Class 1      | 4.52E-05   | 2.98E-04 | 7.99E-04    |
| Class 2      | 2.71E-05   | 2.33E-04 | 6.49E-04    |
| Class 3      | 3.88E-05   | 3.91E-04 | 1.17E-03    |
| Class 4      | 4.80E-05   | 2.98E-04 | 8.01E-04    |
| Class 5      | 2.71E-05   | 1.78E-04 | 4.63E-04    |
| Class 6      | 1.43E-06   | 4.06E-05 | 1.44E-04    |

Figure 2 displays the trend by fiscal year of the HPI system FTS unavailability calculated from the 1987–2002 experience. Table 8 shows the data points for Figure 2. The trend is not considered statistically significant.<sup>1</sup>

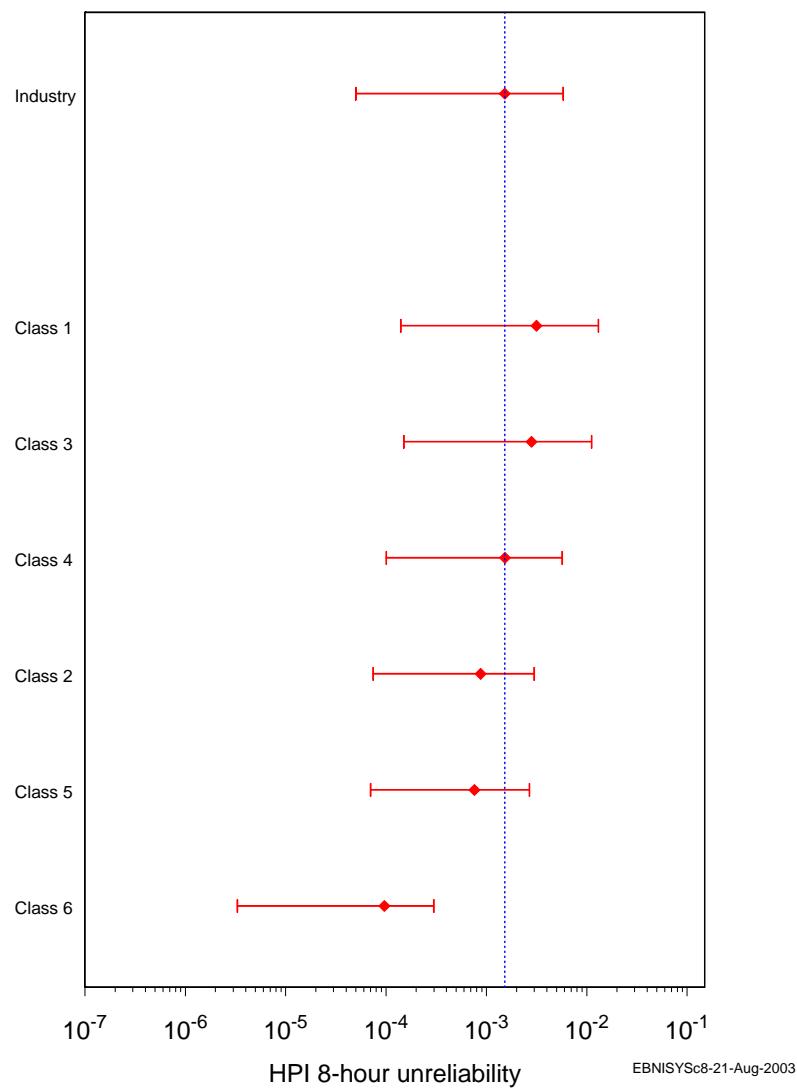


**Figure 2. Trend of HPI system unavailability (FTS model), as a function of fiscal year.**

### 1.3 Fail to Operate for 8-Hour Model

The unreliability of the HPI system for each design class has been calculated from the operating experience for the 8-hour mission. The waterfall plot is shown in Figure 3 and the data table is shown in Table 4. The 1987–2002 HPI operational experience includes zero total system failures and three HPI segment failures. Due to the sparseness of the data, between-plant variation of failure probabilities would not be meaningful.

<sup>1</sup> The term “statistically significant” means that the data are too closely correlated to be attributed to chance and consequently have a systematic relationship. A p-value of less than 0.05 is generally considered statistically significant.

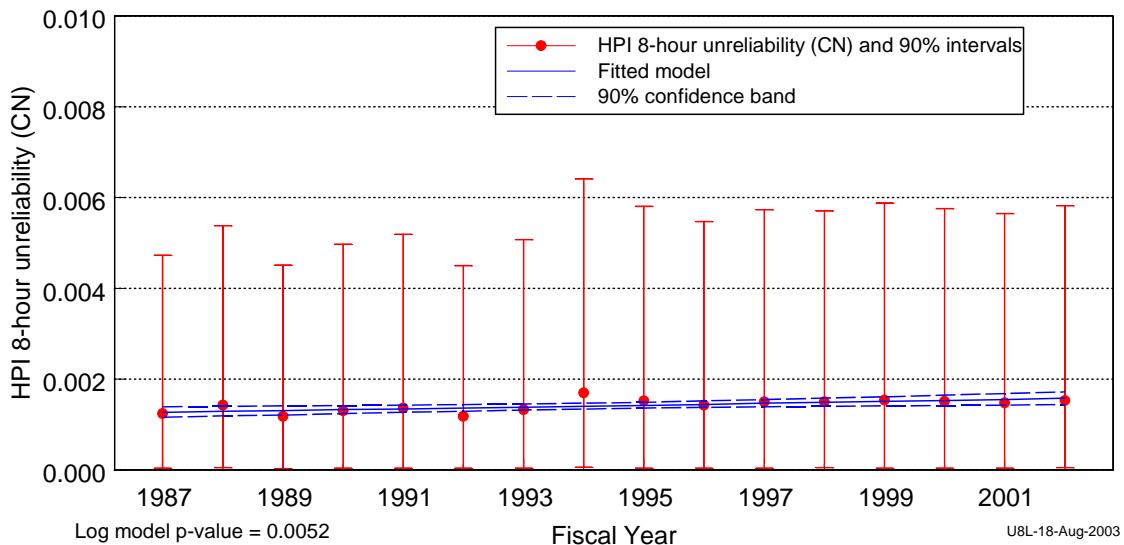


**Figure 3. HPI design class unreliability (8-hour model).**

**Table 4. HPI unreliability (8-hour model) by design class.**

| Design Class | Lower (5%) | Mean     | Upper (95%) |
|--------------|------------|----------|-------------|
| Industry     | 4.50E-05   | 1.52E-03 | 5.79E-03    |
| Class 1      | 1.39E-04   | 3.16E-03 | 1.30E-02    |
| Class 2      | 7.38E-05   | 8.76E-04 | 2.98E-03    |
| Class 3      | 1.46E-04   | 2.81E-03 | 1.12E-02    |
| Class 4      | 1.02E-04   | 1.53E-03 | 5.68E-03    |
| Class 5      | 6.97E-05   | 7.62E-04 | 2.68E-03    |
| Class 6      | 3.33E-06   | 9.63E-05 | 2.99E-04    |

A statistically significant increasing<sup>2</sup> trend within the industry estimates of HPI system unreliability (8-hour mission) on a per fiscal year basis was identified. [Figure 4](#) displays the trend by fiscal year of the HPI system unreliability calculated from the 1987–2002 experience. [Table 9](#) shows the data points for [Figure 4](#).



**Figure 4.** Trend of HPI system unreliability (8-hour mission), as a function of fiscal year.

<sup>2</sup> The increasing trend is due to the number of demands falling over time (see [Figure 5](#)). Decreasing the demands can have the effect of increasing the failure probability.

## 2 DATA TRENDS

### 2.1 Unplanned Demand Trend

Trends were identified in the frequency of HPI unplanned demands (Figure 5). When modeled as a function of fiscal year, the unplanned demand frequency exhibited a highly statistically significant decreasing trend. Table 10 shows the LERs that are represented in the figure.

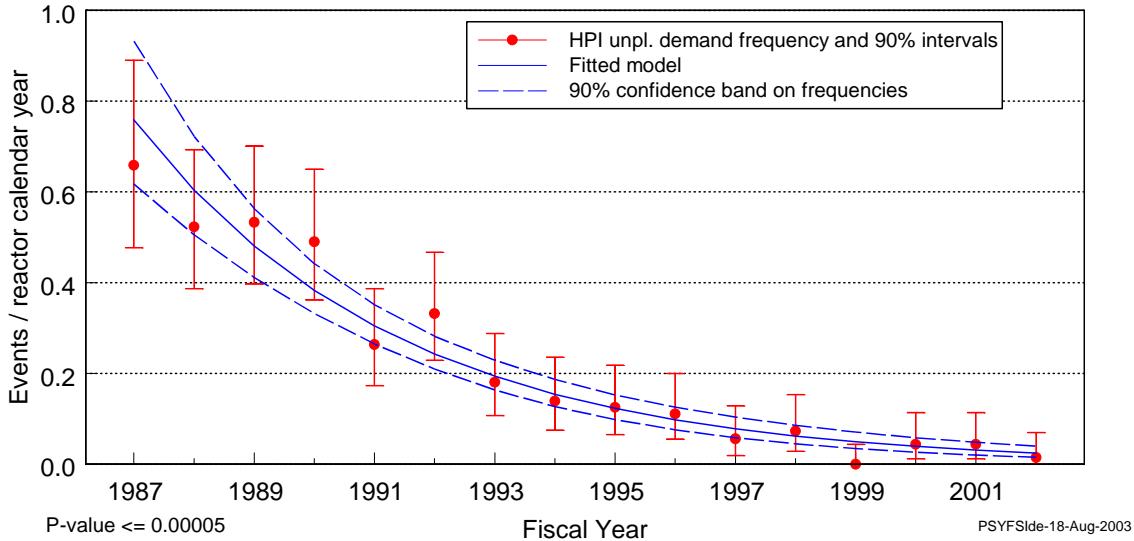
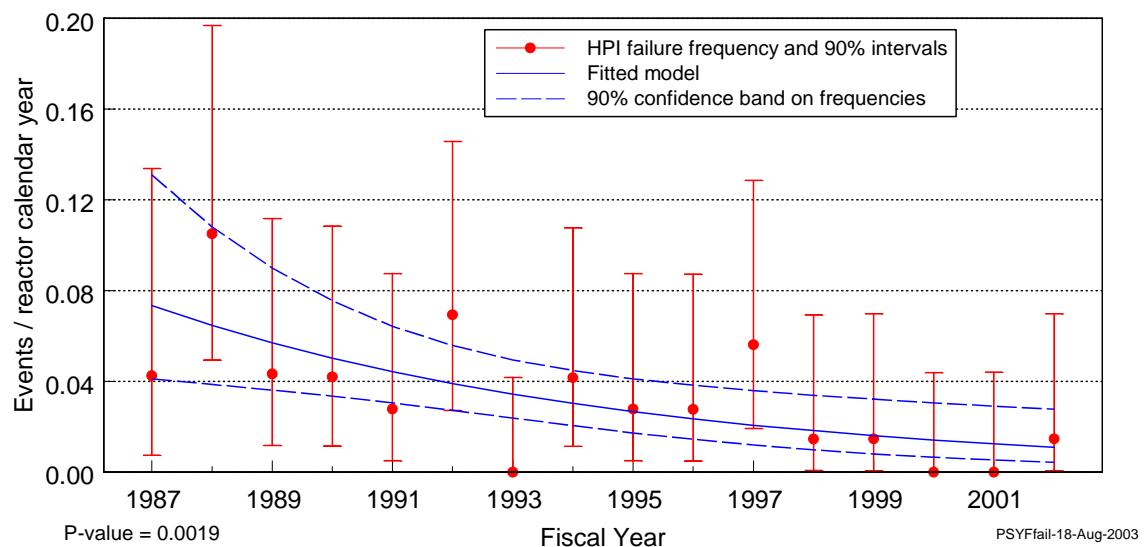


Figure 5. Frequency (events per operating year) of unplanned demands, as a function of fiscal year.

### 2.2 Failure Trend

The frequency of all failures (unplanned demands, surveillance tests, inspections, etc.) resulting in train unavailability identified in the experience was analyzed to determine trends. When modeled as a function of fiscal year, a highly statistically significant decreasing trend was identified. The fitted frequency is plotted against fiscal year in Figure 6. Trends for HPI failures are plotted without regard to method of detection (the trend excludes maintenance out of service and support system failures). Table 11 shows the LERs that are represented in the figure.



**Figure 6. Frequency (events per operating year) of failures, as a function of fiscal year.**

### 3 MAJOR CONTRIBUTORS TO SYSTEM UNRELIABILITY AND UNAVAILABILITY

#### 3.1 Segment Failure Contribution to Design Class Models

The segment failure contribution has been calculated by adding up the segment failures of each cut-set for each design class fault tree model. Only the top five segment failures are shown.

##### 3.1.1 Fail to Start Model

Figure 7 through Figure 12 show the distributions of segment failures for the FTS model. The top segment failure varies between the Design Classes. Design Classes 4 and 5 have the pump fail-to-start as the top segment failure. Design Classes 1, 2, and 6 have the injection header MOVs as the top segment failure. Design Class 3 shows the injection header check valves as the top segment failure (Design Class 3 has a running pump and does not require any start for this model). Design Class 3 shows common-cause failure of injection header MOVs and Design Class 5 shows common-cause failure of the pump to start.

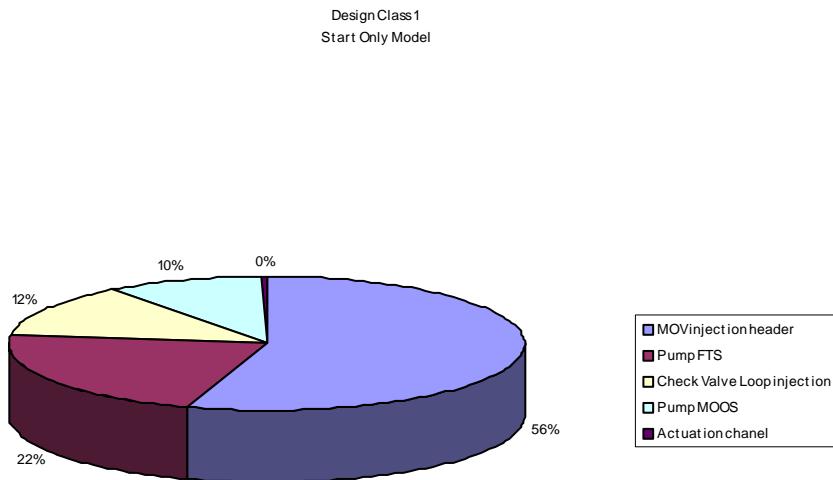
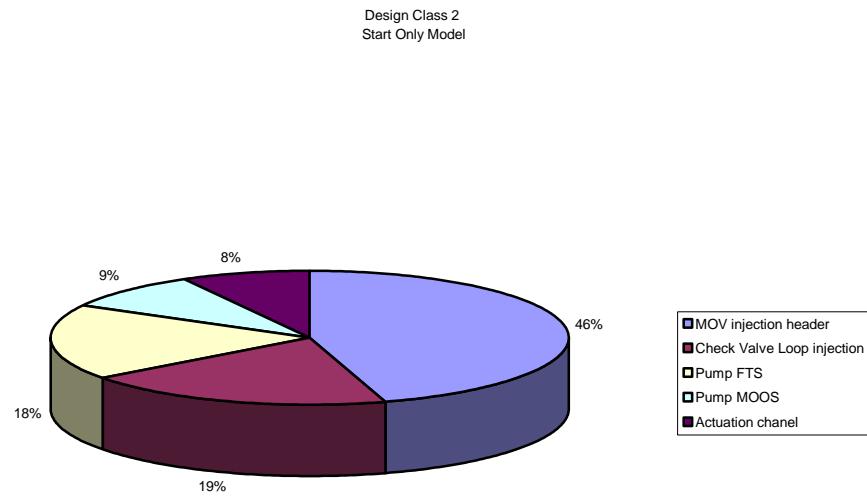
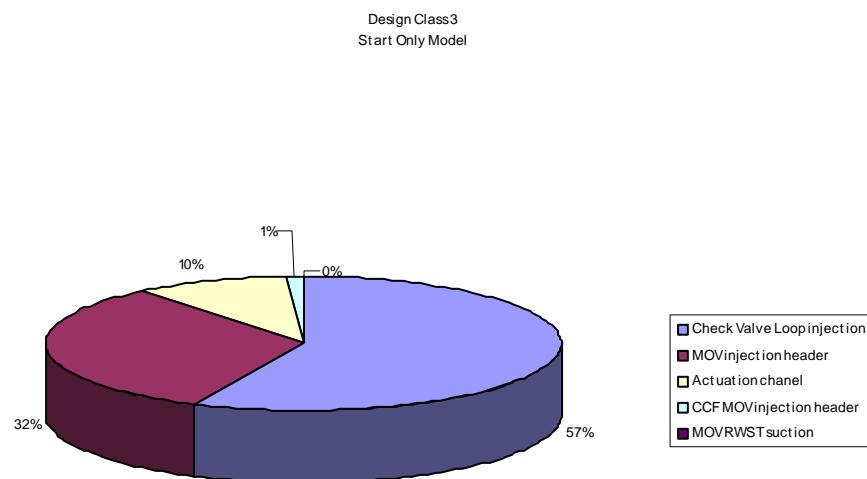


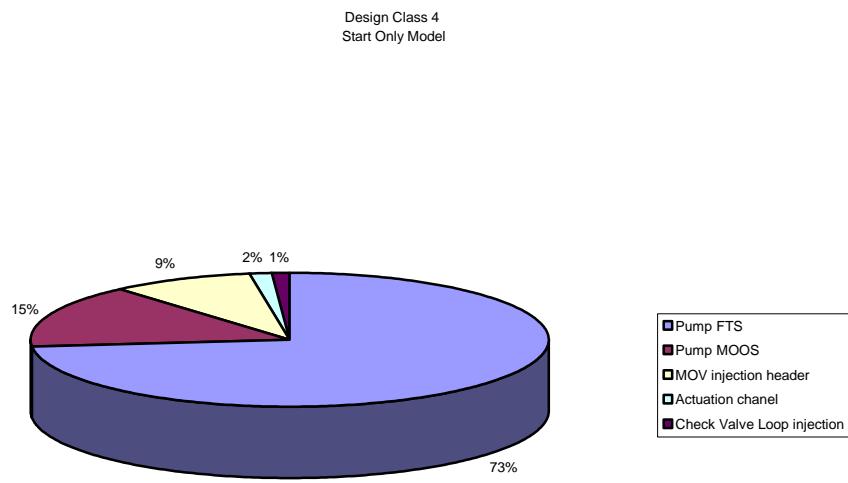
Figure 7. Segment failure distribution, FTS model Design Class 1.



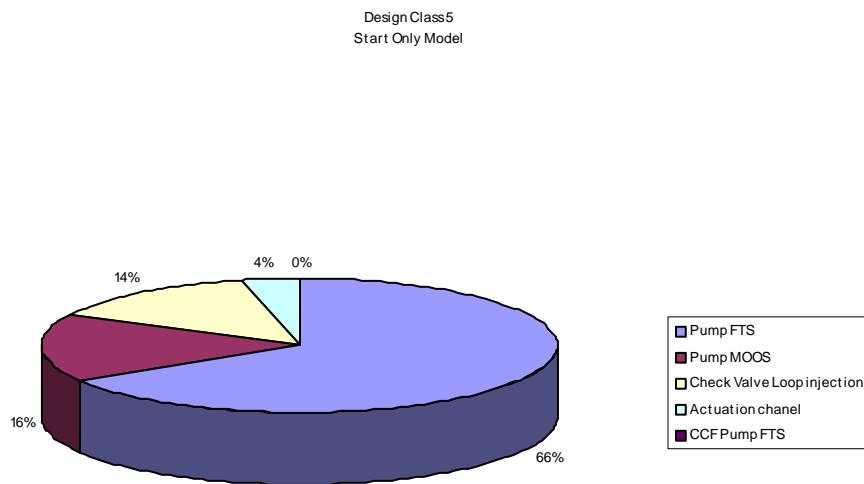
**Figure 8. Segment failure distribution, FTS model Design Class 2.**



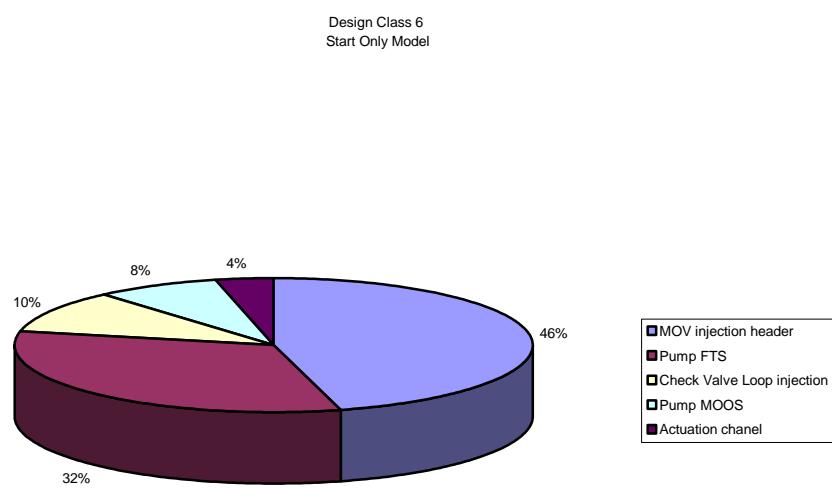
**Figure 9. Segment failure distribution, FTS model Design Class 3.**



**Figure 10.** Segment failure distribution, FTS model Design Class 4.



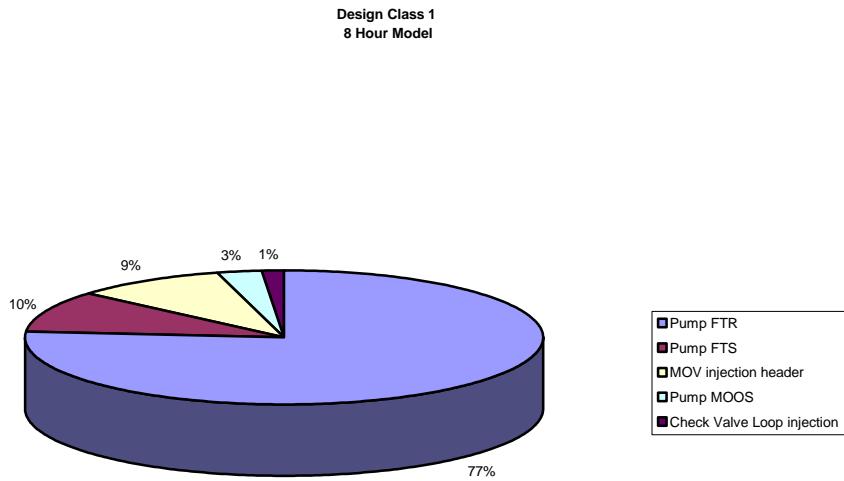
**Figure 11.** Segment failure distribution, FTS model Design Class 5.



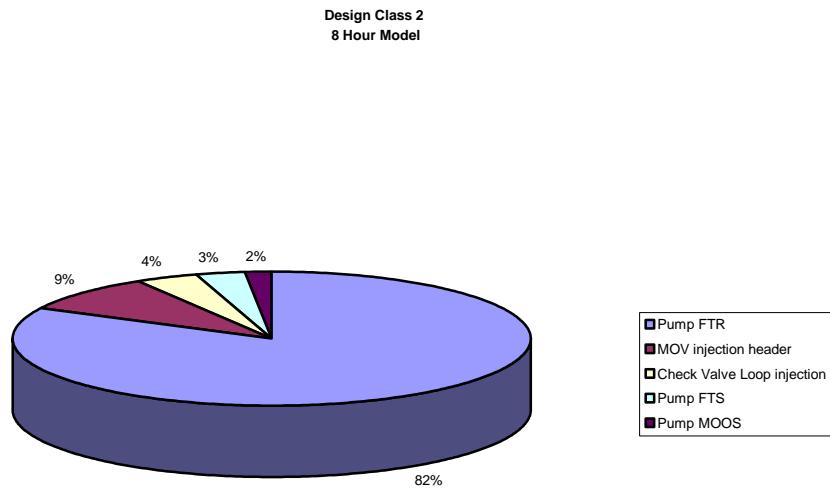
**Figure 12. Segment failure distribution, FTS model Design Class 6.**

### 3.1.2 Fail to Operate for 8 –hour Model

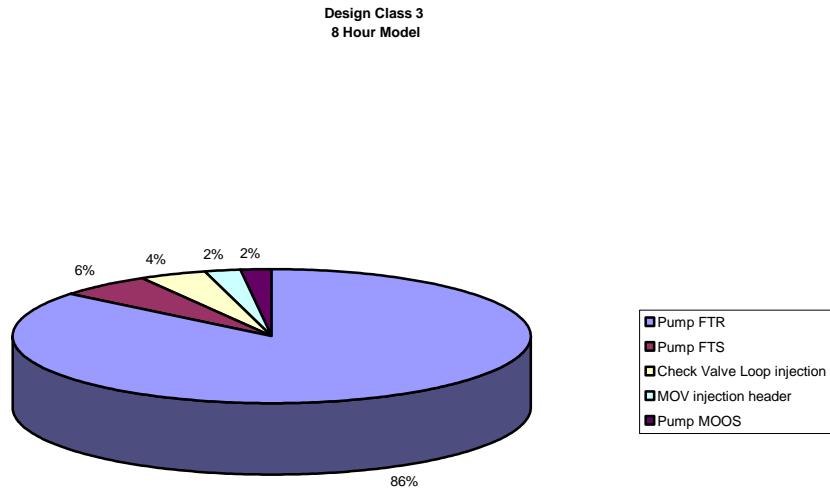
Figure 13 through Figure 18 show the distributions of segment failures for the 8-hour model. The pump fail-to-run segment failure is the highest contributor for each of the design classes. Only Design Class 6 shows common-cause failure (pump fail-to-run) in the top five segment failures.



**Figure 13. Segment failure distribution, 8-hour mission Design Class 1.**



**Figure 14.** Segment failure distribution, 8-hour mission Design Class 2.



**Figure 15.** Segment failure distribution, 8-hour mission Design Class 3.

Design Class 4  
8 Hour Model

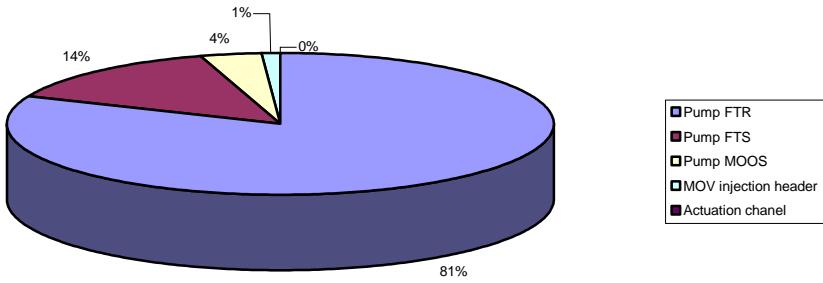


Figure 16. Segment failure distribution, 8-hour mission Design Class 4.

Design Class 5  
8 Hour Model

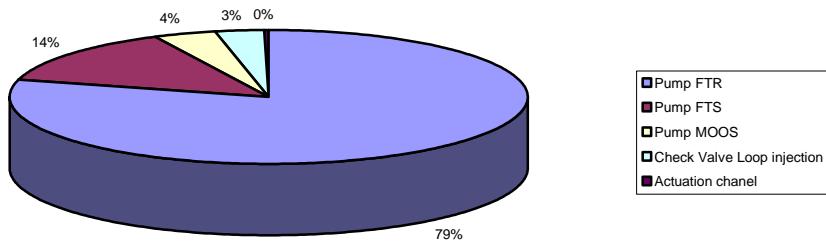
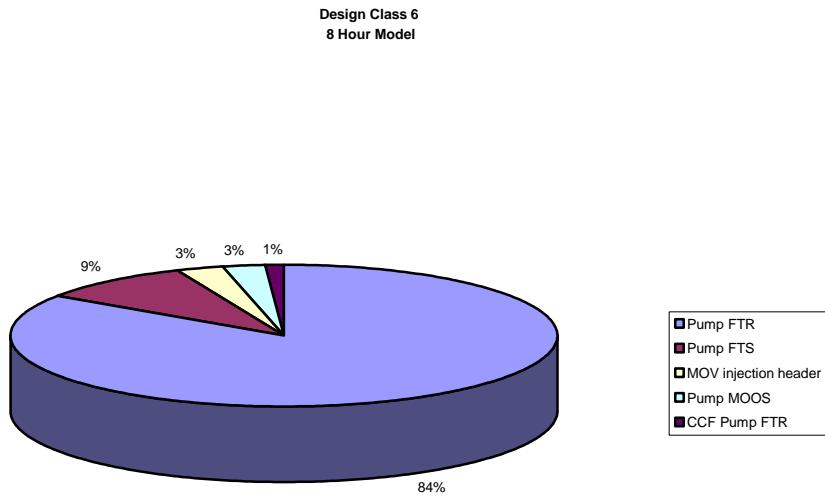


Figure 17. Segment failure distribution, 8-hour mission Design Class 5.



**Figure 18.** Segment failure distribution, 8-hour mission Design Class 6.

## 3.2 Failure Cause and Discovery Method Summary

The raw failure data were sliced to show the distribution of the failure causes and the discovery methods by the affected segment.

### 3.2.1 Leading Segment Failures.

The pump (79%) and the actuation circuit (9%) were the leading segment failures identified in the database. See [Table 5](#).

### 3.2.2 Leading Discovery Methods

Periodic surveillance (27%) and Non-SI demand (27%) were the leading methods of discovery. See [Table 5](#).

### 3.2.3 Leading Causes of Failure.

Fifty-two percent failures of the HPI system observed in the experience were attributed to hardware-related problems. Personnel errors led to 24% of all HPI segment failures. However, 50% of these failures were immediately identified and either recovered or were recoverable, meaning that the failures were of the nature where plant personnel were able to respond to the failures immediately after they occurred. See [Table 7](#)

**Table 5. Comparison of failed segment with the method of discovery.<sup>3</sup>**

| Segment   | SI Demand | Non-SI Demand | Alarm/ indicator | Inspection/ review | Other (not counted) surveillance test | Periodic surveillance | Total | Percent |
|-----------|-----------|---------------|------------------|--------------------|---------------------------------------|-----------------------|-------|---------|
| Actuation |           |               |                  |                    |                                       |                       |       |         |
| Circuit   | 3         |               |                  |                    |                                       |                       | 3     | 9%      |
| Motor     |           | 1             |                  |                    |                                       |                       | 1     | 3%      |
| Other     |           |               |                  |                    |                                       | 1                     | 1     | 3%      |
| Pump      | 1         | 8             | 7                | 1                  | 1                                     | 8                     | 26    | 79%     |
| Valve     | 1         |               |                  |                    | 1                                     |                       | 2     | 6%      |
| Total     | 5         | 9             | 7                | 1                  | 2                                     | 9                     | 33    | 100%    |
| Percent   | 15%       | 27%           | 21%              | 3%                 | 6%                                    | 27%                   | 100%  |         |

**Table 6. Discovery method description.**

| Discovery Method                        | Description  | Used in the Failure Calculations |
|---|--|----------------------------------|
| SI Demand                               | The failure was discovered during a safety injection demand.   | ✓                                |
| Non-SI Demand                           | The failure was discovered during any other type of demand than SI.  |                                  |
| Periodic surveillance on subject system | Normally scheduled surveillances. These surveillances are to satisfy scheduled Technical Specification requirements. | ✓                                |
| Inspection/review                       | The failure was discovered during operator duties such as walk downs, inspections, etc.                              |                                  |
| Alarm/indicator                         | The failure was evidenced by an alarm or by other indications.   |                                  |
| Other (not counted) surveillance test   | All others discovered by testing.  |                                  |

<sup>3</sup> The discovery method is the activity that is ongoing at the time of the failure.

**Table 7. Comparison of failed segment and failure cause.<sup>4</sup>**

| Segment           | Design | Gas Binding | Hardware | Maintenance | Personnel | Procedure | Total | Percent |
|-------------------|--------|-------------|----------|-------------|-----------|-----------|-------|---------|
| Actuation Circuit | 1      |             | 1        |             | 1         |           | 3     | 9%      |
| Motor             |        |             | 1        |             |           |           | 1     | 3%      |
| Other             |        |             | 1        |             |           |           | 1     | 3%      |
| Pump              | 1      | 4           | 13       | 1           | 6         | 1         | 26    | 79%     |
| Valve             |        |             | 1        |             | 1         |           | 2     | 6%      |
| Total             | 2      | 4           | 17       | 1           | 8         | 1         | 33    | 100%    |
| Percent           | 6%     | 12%         | 52%      | 3%          | 24%       | 3%        | 100%  |         |

- Contamination—The failure was the result of foreign material affecting the component.
- Design—The failure was the result of a flawed design.
- Hardware—The failure was the result of some aspect of the equipment. Typically, this is used for normal wear of the component.
- Personnel—The failure was the result of personnel error, by either commission or omission.
- Procedure—The failure was the result of an incorrect procedure.
- Gas Binding—The failure was the result of gases coming out of solution in the pump suction. This cause is used only in the HPI study.

<sup>4</sup> The cause of the failure is assigned to a broadly defined cause classification. The cause classifications are design, environment, hardware (e.g., aging, wear, manufacturing defects), personnel, and procedure. The cause classification assigned is based on the immediate cause of the failure and not the root cause. Generally, root cause is only determined through a detailed investigation and analysis of the failure. Specifically, the mechanism that actually resulted in the failure of the segment or component is captured as the cause.

## 4 DATA TABLES

### 4.1 Data Tables for Unreliability and Unavailability Trends

**Table 8.** Plot data table for HPI system unavailability, FTS model. [Figure 2](#)

| Fiscal Year | Plot Trend Error Bar Points |          |                | Regression Curve Data Points |          |                |
|-------------|-----------------------------|----------|----------------|------------------------------|----------|----------------|
|             | Lower<br>(5%)               | Mean     | Upper<br>(95%) | Lower<br>(5%)                | Mean     | Upper<br>(95%) |
| 1987        | 1.08E-05                    | 1.33E-04 | 4.51E-04       | 1.23E-04                     | 1.76E-04 | 2.29E-04       |
| 1988        | 2.46E-05                    | 2.96E-04 | 1.00E-03       | 1.28E-04                     | 1.76E-04 | 2.24E-04       |
| 1989        | 1.63E-05                    | 1.48E-04 | 4.70E-04       | 1.32E-04                     | 1.76E-04 | 2.19E-04       |
| 1990        | 1.09E-05                    | 1.41E-04 | 4.83E-04       | 1.37E-04                     | 1.76E-04 | 2.15E-04       |
| 1991        | 1.12E-05                    | 1.47E-04 | 5.05E-04       | 1.41E-04                     | 1.76E-04 | 2.11E-04       |
| 1992        | 1.03E-05                    | 1.32E-04 | 4.52E-04       | 1.44E-04                     | 1.76E-04 | 2.08E-04       |
| 1993        | 1.16E-05                    | 1.53E-04 | 5.26E-04       | 1.46E-04                     | 1.76E-04 | 2.05E-04       |
| 1994        | 2.32E-05                    | 2.78E-04 | 9.40E-04       | 1.48E-04                     | 1.76E-04 | 2.04E-04       |
| 1995        | 1.20E-05                    | 1.74E-04 | 6.06E-04       | 1.47E-04                     | 1.76E-04 | 2.04E-04       |
| 1996        | 1.16E-05                    | 1.65E-04 | 5.76E-04       | 1.46E-04                     | 1.76E-04 | 2.05E-04       |
| 1997        | 1.21E-05                    | 1.70E-04 | 5.92E-04       | 1.44E-04                     | 1.76E-04 | 2.07E-04       |
| 1998        | 1.22E-05                    | 1.74E-04 | 6.07E-04       | 1.40E-04                     | 1.76E-04 | 2.11E-04       |
| 1999        | 1.22E-05                    | 1.78E-04 | 6.23E-04       | 1.36E-04                     | 1.75E-04 | 2.15E-04       |
| 2000        | 1.20E-05                    | 1.72E-04 | 5.98E-04       | 1.32E-04                     | 1.75E-04 | 2.19E-04       |
| 2001        | 1.20E-05                    | 1.74E-04 | 6.06E-04       | 1.27E-04                     | 1.75E-04 | 2.24E-04       |
| 2002        | 1.23E-05                    | 1.76E-04 | 6.14E-04       | 1.22E-04                     | 1.75E-04 | 2.29E-04       |

**Table 9.** Plot data table for HPI system unreliability, 8-hour mission. [Figure 4](#)

| Fiscal Year | Plot Trend Error Bar Points |          |                | Regression Curve Data Points |          |                |
|-------------|-----------------------------|----------|----------------|------------------------------|----------|----------------|
|             | Lower<br>(5%)               | Mean     | Upper<br>(95%) | Lower<br>(5%)                | Mean     | Upper<br>(95%) |
| 1987        | 3.58E-05                    | 1.24E-03 | 4.73E-03       | 1.15E-03                     | 1.27E-03 | 1.40E-03       |
| 1988        | 5.22E-05                    | 1.43E-03 | 5.38E-03       | 1.18E-03                     | 1.29E-03 | 1.41E-03       |
| 1989        | 3.56E-05                    | 1.18E-03 | 4.51E-03       | 1.21E-03                     | 1.31E-03 | 1.42E-03       |
| 1990        | 3.77E-05                    | 1.30E-03 | 4.97E-03       | 1.24E-03                     | 1.33E-03 | 1.42E-03       |
| 1991        | 3.94E-05                    | 1.36E-03 | 5.20E-03       | 1.27E-03                     | 1.35E-03 | 1.43E-03       |
| 1992        | 3.46E-05                    | 1.18E-03 | 4.50E-03       | 1.30E-03                     | 1.37E-03 | 1.45E-03       |
| 1993        | 3.94E-05                    | 1.33E-03 | 5.07E-03       | 1.32E-03                     | 1.39E-03 | 1.46E-03       |
| 1994        | 6.02E-05                    | 1.70E-03 | 6.41E-03       | 1.34E-03                     | 1.41E-03 | 1.48E-03       |
| 1995        | 4.49E-05                    | 1.52E-03 | 5.81E-03       | 1.36E-03                     | 1.43E-03 | 1.50E-03       |
| 1996        | 4.25E-05                    | 1.43E-03 | 5.47E-03       | 1.38E-03                     | 1.45E-03 | 1.52E-03       |
| 1997        | 4.42E-05                    | 1.50E-03 | 5.73E-03       | 1.40E-03                     | 1.47E-03 | 1.55E-03       |
| 1998        | 4.45E-05                    | 1.50E-03 | 5.70E-03       | 1.41E-03                     | 1.49E-03 | 1.57E-03       |
| 1999        | 4.57E-05                    | 1.54E-03 | 5.88E-03       | 1.42E-03                     | 1.51E-03 | 1.60E-03       |
| 2000        | 4.44E-05                    | 1.51E-03 | 5.76E-03       | 1.43E-03                     | 1.53E-03 | 1.63E-03       |
| 2001        | 4.41E-05                    | 1.48E-03 | 5.66E-03       | 1.44E-03                     | 1.55E-03 | 1.66E-03       |
| 2002        | 4.53E-05                    | 1.53E-03 | 5.82E-03       | 1.44E-03                     | 1.57E-03 | 1.70E-03       |

## 4.2 Data Tables for Failure and Demand Trends

**Table 10. LER listing for demand trend figure.  
Figure 5**

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1996 | Arkansas 1       | 5/19/1996  | <a href="#">3131996005</a> |
| 1994 | Arkansas 1       | 4/11/1994  | <a href="#">3131994002</a> |
| 1989 | Arkansas 1       | 1/20/1989  | <a href="#">3131989002</a> |
| 1992 | Arkansas 2       | 9/9/1992   | <a href="#">3681992006</a> |
| 1990 | Arkansas 2       | 10/17/1989 | <a href="#">3681989018</a> |
| 1989 | Arkansas 2       | 12/1/1988  | <a href="#">3681988020</a> |
| 1989 | Arkansas 2       | 6/26/1989  | <a href="#">3681989012</a> |
| 1988 | Arkansas 2       | 4/23/1988  | <a href="#">3681988007</a> |
| 1988 | Arkansas 2       | 3/10/1988  | <a href="#">3681988003</a> |
| 1988 | Arkansas 2       | 8/1/1988   | <a href="#">3681988011</a> |
| 1995 | Beaver Valley 1  | 2/19/1995  | <a href="#">3341995003</a> |
| 1990 | Beaver Valley 1  | 12/13/1989 | <a href="#">3341989015</a> |
| 1989 | Beaver Valley 1  | 5/18/1989  | <a href="#">3341989007</a> |
| 1988 | Beaver Valley 1  | 6/7/1988   | <a href="#">3341988007</a> |
| 1994 | Beaver Valley 2  | 3/15/1994  | <a href="#">4121994004</a> |
| 1993 | Beaver Valley 2  | 1/30/1993  | <a href="#">4121993002</a> |
| 1992 | Beaver Valley 2  | 5/1/1992   | <a href="#">4121992006</a> |
| 1989 | Beaver Valley 2  | 3/22/1989  | <a href="#">4121989005</a> |
| 1988 | Beaver Valley 2  | 2/1/1988   | <a href="#">4121988004</a> |
| 1987 | Beaver Valley 2  | 7/30/1987  | <a href="#">4121987011</a> |
| 1987 | Beaver Valley 2  | 9/29/1987  | <a href="#">4121987024</a> |
| 1987 | Beaver Valley 2  | 6/29/1987  | <a href="#">4121987002</a> |
| 1993 | Braidwood 1      | 10/23/1992 | <a href="#">4561992013</a> |
| 1990 | Braidwood 1      | 10/30/1989 | <a href="#">4561989014</a> |
| 1990 | Braidwood 1      | 9/29/1990  | <a href="#">4561990018</a> |
| 1989 | Braidwood 1      | 4/16/1989  | <a href="#">4561989002</a> |
| 1988 | Braidwood 1      | 12/11/1987 | <a href="#">4561987062</a> |
| 1988 | Braidwood 1      | 1/25/1988  | <a href="#">4561988002</a> |
| 1990 | Braidwood 2      | 3/18/1990  | <a href="#">4571990002</a> |
| 1990 | Braidwood 2      | 4/5/1990   | <a href="#">4571990003</a> |
| 1992 | Byron 1          | 10/16/1991 | <a href="#">4541991004</a> |
| 1987 | Byron 1          | 8/12/1987  | <a href="#">4541987019</a> |
| 1987 | Byron 1          | 2/25/1987  | <a href="#">4541987004</a> |
| 1987 | Byron 1          | 4/8/1987   | <a href="#">4541987009</a> |
| 1993 | Byron 2          | 9/5/1993   | <a href="#">4551993004</a> |
| 1990 | Byron 2          | 9/3/1990   | <a href="#">4551990006</a> |
| 1990 | Byron 2          | 1/18/1990  | <a href="#">4551990001</a> |
| 1989 | Byron 2          | 2/11/1989  | <a href="#">4551989001</a> |
| 1987 | Byron 2          | 8/31/1987  | <a href="#">4551987016</a> |
| 1989 | Callaway         | 5/18/1989  | <a href="#">4831989005</a> |
| 1988 | Callaway         | 2/13/1988  | <a href="#">4831988004</a> |
| 1995 | Calvert Cliffs 1 | 5/27/1995  | <a href="#">3171997005</a> |
| 1990 | Calvert Cliffs 1 | 3/8/1990   | <a href="#">3171990003</a> |
| 1990 | Calvert Cliffs 1 | 8/2/1990   | <a href="#">3171990023</a> |
| 1989 | Calvert Cliffs 1 | 3/19/1989  | <a href="#">3171989003</a> |
| 1989 | Calvert Cliffs 1 | 3/20/1989  | <a href="#">3171989004</a> |

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1988 | Calvert Cliffs 1 | 5/2/1988   | <a href="#">3171988002</a> |
| 1991 | Calvert Cliffs 2 | 3/27/1991  | <a href="#">3181991002</a> |
| 2001 | Catawba 1        | 11/10/2000 | <a href="#">4132000006</a> |
| 1998 | Catawba 1        | 12/30/1997 | <a href="#">4131997011</a> |
| 1989 | Catawba 1        | 3/5/1989   | <a href="#">4131989008</a> |
| 1988 | Catawba 1        | 1/23/1988  | <a href="#">4131988007</a> |
| 1998 | Catawba 2        | 9/6/1998   | <a href="#">4141998004</a> |
| 1996 | Catawba 2        | 2/6/1996   | <a href="#">4141996001</a> |
| 1989 | Catawba 2        | 2/21/1989  | <a href="#">4141989003</a> |
| 1989 | Catawba 2        | 2/21/1989  | <a href="#">4141989004</a> |
| 1988 | Catawba 2        | 2/9/1988   | <a href="#">4141988003</a> |
| 1996 | Comanche Peak 1  | 1/17/1996  | <a href="#">4451996001</a> |
| 1993 | Comanche Peak 1  | 2/26/1993  | <a href="#">4451993003</a> |
| 1992 | Comanche Peak 1  | 6/23/1992  | <a href="#">4451992016</a> |
| 1991 | Comanche Peak 1  | 11/5/1990  | <a href="#">4451990037</a> |
| 1991 | Comanche Peak 1  | 9/4/1991   | <a href="#">4451991022</a> |
| 1990 | Comanche Peak 1  | 7/30/1990  | <a href="#">4451990021</a> |
| 1990 | Comanche Peak 1  | 7/26/1990  | <a href="#">4451990020</a> |
| 1990 | Comanche Peak 1  | 3/12/1990  | <a href="#">4451990004</a> |
| 1988 | Cook 2           | 10/2/1987  | <a href="#">3161987011</a> |
| 1993 | Crystal River 3  | 9/18/1993  | <a href="#">3021993009</a> |
| 1992 | Crystal River 3  | 12/8/1991  | <a href="#">3021991018</a> |
| 1989 | Crystal River 3  | 10/14/1988 | <a href="#">3021988021</a> |
| 1988 | Crystal River 3  | 11/20/1987 | <a href="#">3021987030</a> |
| 1988 | Crystal River 3  | 11/6/1987  | <a href="#">3021987022</a> |
| 1987 | Crystal River 3  | 7/10/1987  | <a href="#">3021987011</a> |
| 1991 | Diablo Canyon 1  | 3/23/1991  | <a href="#">2751991005</a> |
| 1991 | Diablo Canyon 1  | 5/17/1991  | <a href="#">2751991009</a> |
| 1991 | Diablo Canyon 1  | 12/24/1990 | <a href="#">2751990017</a> |
| 1990 | Diablo Canyon 1  | 10/6/1989  | <a href="#">2751989009</a> |
| 1998 | Diablo Canyon 2  | 10/24/1997 | <a href="#">3231997005</a> |
| 1992 | Diablo Canyon 2  | 10/6/1991  | <a href="#">3231991007</a> |
| 1988 | Diablo Canyon 2  | 7/17/1988  | <a href="#">3231988008</a> |
| 1987 | Diablo Canyon 2  | 3/21/1987  | <a href="#">3231987003</a> |
| 1987 | Diablo Canyon 2  | 7/14/1987  | <a href="#">3231987016</a> |
| 1987 | Diablo Canyon 2  | 4/3/1987   | <a href="#">3231987004</a> |
| 1990 | Farley 1         | 11/12/1989 | <a href="#">3481989006</a> |
| 1993 | Farley 2         | 2/5/1993   | <a href="#">3641993001</a> |
| 1992 | Farley 2         | 5/2/1992   | <a href="#">3641992003</a> |
| 1991 | Farley 2         | 11/16/1990 | <a href="#">3641990004</a> |
| 1989 | Farley 2         | 4/29/1989  | <a href="#">3641989005</a> |
| 1994 | Fort Calhoun     | 2/11/1994  | <a href="#">2851994001</a> |
| 1992 | Fort Calhoun     | 7/3/1992   | <a href="#">2851992023</a> |
| 1990 | Fort Calhoun     | 4/2/1990   | <a href="#">2851990011</a> |
| 1990 | Fort Calhoun     | 3/6/1990   | <a href="#">2851990008</a> |
| 1989 | Fort Calhoun     | 12/31/1988 | <a href="#">2851988038</a> |
| 1987 | Fort Calhoun     | 5/20/1987  | <a href="#">2851987015</a> |
| 1987 | Fort Calhoun     | 4/13/1987  | <a href="#">2851987012</a> |

| FY   | Plant          | Date       | LER                        |
|------|----------------|------------|----------------------------|
| 1987 | Fort Calhoun   | 3/27/1987  | <a href="#">2851987006</a> |
| 1987 | Fort Calhoun   | 4/28/1987  | <a href="#">2851987011</a> |
| 1998 | Ginna          | 10/31/1997 | <a href="#">2441997005</a> |
| 1995 | Ginna          | 4/7/1995   | <a href="#">2441995003</a> |
| 1990 | Ginna          | 5/5/1990   | <a href="#">2441990006</a> |
| 1989 | Ginna          | 5/18/1989  | <a href="#">2441989003</a> |
| 1988 | Ginna          | 6/1/1988   | <a href="#">2441988005</a> |
| 1995 | Haddam Neck    | 7/27/1995  | <a href="#">2131995016</a> |
| 2000 | Harris         | 5/4/2000   | <a href="#">4002000003</a> |
| 1997 | Harris         | 5/14/1997  | <a href="#">4001997014</a> |
| 1996 | Harris         | 11/5/1995  | <a href="#">4001995011</a> |
| 1996 | Harris         | 10/5/1995  | <a href="#">4001995009</a> |
| 1988 | Harris         | 11/7/1987  | <a href="#">4001987062</a> |
| 2000 | Indian Point 2 | 2/15/2000  | <a href="#">2472000001</a> |
| 1997 | Indian Point 2 | 5/2/1997   | <a href="#">2471997009</a> |
| 1997 | Indian Point 2 | 5/1/1997   | <a href="#">2471997010</a> |
| 1992 | Indian Point 2 | 1/27/1992  | <a href="#">2471992002</a> |
| 1988 | Indian Point 2 | 1/17/1988  | <a href="#">2471988001</a> |
| 1995 | Indian Point 3 | 4/29/1995  | <a href="#">2861995009</a> |
| 1989 | Indian Point 3 | 2/4/1989   | <a href="#">2861989001</a> |
| 1987 | Indian Point 3 | 2/11/1987  | <a href="#">2861987002</a> |
| 1987 | Indian Point 3 | 4/17/1987  | <a href="#">2861987004</a> |
| 1987 | Indian Point 3 | 9/3/1987   | <a href="#">2861987010</a> |
| 1988 | Keweenaw       | 3/28/1988  | <a href="#">3051988002</a> |
| 1992 | Maine Yankee   | 2/25/1992  | <a href="#">3091992002</a> |
| 1990 | Maine Yankee   | 4/14/1990  | <a href="#">3091990002</a> |
| 1989 | Maine Yankee   | 12/22/1988 | <a href="#">3091988011</a> |
| 1992 | McGuire 1      | 10/13/1991 | <a href="#">3691991015</a> |
| 1991 | McGuire 1      | 2/11/1991  | <a href="#">3691991001</a> |
| 1989 | McGuire 1      | 3/7/1989   | <a href="#">3691989004</a> |
| 1988 | McGuire 1      | 3/23/1988  | <a href="#">3691988005</a> |
| 1987 | McGuire 1      | 8/16/1987  | <a href="#">3691987017</a> |
| 1987 | McGuire 1      | 7/9/1987   | <a href="#">3691987012</a> |
| 1997 | McGuire 2      | 5/27/1997  | <a href="#">3701997001</a> |
| 1994 | McGuire 2      | 12/27/1993 | <a href="#">3701993008</a> |
| 1993 | McGuire 2      | 3/22/1993  | <a href="#">3701993003</a> |
| 1994 | Millstone 2    | 5/13/1994  | <a href="#">3361994010</a> |
| 1990 | Millstone 2    | 9/19/1990  | <a href="#">3361990015</a> |
| 1995 | Millstone 3    | 4/16/1995  | <a href="#">4231995007</a> |
| 1990 | Millstone 3    | 12/11/1989 | <a href="#">4231989034</a> |
| 1990 | Millstone 3    | 1/9/1990   | <a href="#">4231990002</a> |
| 1990 | Millstone 3    | 12/5/1989  | <a href="#">4231989033</a> |
| 1989 | Millstone 3    | 2/17/1989  | <a href="#">4231989005</a> |
| 1988 | Millstone 3    | 1/5/1988   | <a href="#">4231988001</a> |
| 1987 | Millstone 3    | 3/25/1987  | <a href="#">4231987016</a> |
| 1991 | North Anna 1   | 7/14/1991  | <a href="#">3381991015</a> |
| 1991 | North Anna 1   | 8/8/1991   | <a href="#">3381991017</a> |
| 1987 | North Anna 1   | 7/15/1987  | <a href="#">3381987017</a> |
| 1992 | North Anna 2   | 8/6/1992   | <a href="#">3391992007</a> |
| 1991 | North Anna 2   | 9/20/1991  | <a href="#">3391991009</a> |
| 1988 | North Anna 2   | 7/26/1988  | <a href="#">3391988002</a> |
| 1988 | North Anna 2   | 10/26/1987 | <a href="#">3391987013</a> |
| 1994 | Oconee 1       | 2/26/1994  | <a href="#">2691994002</a> |

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1994 | Oconee 1         | 11/3/1993  | <a href="#">2691993010</a> |
| 1991 | Oconee 1         | 5/16/1991  | <a href="#">2691991006</a> |
| 1990 | Oconee 1         | 5/16/1990  | <a href="#">2691990007</a> |
| 1989 | Oconee 1         | 1/3/1989   | <a href="#">2691989002</a> |
| 1989 | Oconee 1         | 1/2/1989   | <a href="#">2691989001</a> |
| 1997 | Oconee 2         | 7/6/1997   | <a href="#">2701997002</a> |
| 1995 | Oconee 2         | 4/14/1995  | <a href="#">2701995002</a> |
| 1994 | Oconee 2         | 10/24/1993 | <a href="#">2701993007</a> |
| 1994 | Oconee 2         | 4/6/1994   | <a href="#">2701994002</a> |
| 1993 | Oconee 2         | 10/19/1992 | <a href="#">2701992004</a> |
| 1989 | Oconee 2         | 2/5/1989   | <a href="#">2701989003</a> |
| 1989 | Oconee 2         | 2/3/1989   | <a href="#">2701989002</a> |
| 1987 | Oconee 2         | 1/18/1987  | <a href="#">2701987001</a> |
| 1987 | Oconee 2         | 3/26/1987  | <a href="#">2701987002</a> |
| 1991 | Oconee 3         | 11/13/1990 | <a href="#">2871990003</a> |
| 1991 | Oconee 3         | 7/3/1991   | <a href="#">2871991007</a> |
| 1990 | Oconee 3         | 3/7/1990   | <a href="#">2871990002</a> |
| 1990 | Oconee 3         | 11/14/1989 | <a href="#">2871989005</a> |
| 1989 | Oconee 3         | 8/18/1989  | <a href="#">2871989004</a> |
| 1989 | Oconee 3         | 3/6/1989   | <a href="#">2871989002</a> |
| 1995 | Palisades        | 3/2/1995   | <a href="#">2551995001</a> |
| 1995 | Palisades        | 7/21/1995  | <a href="#">2551995005</a> |
| 1990 | Palisades        | 11/21/1989 | <a href="#">2551989025</a> |
| 1992 | Palo Verde 1     | 10/27/1991 | <a href="#">5281991010</a> |
| 1992 | Palo Verde 1     | 5/6/1992   | <a href="#">5281992007</a> |
| 1997 | Palo Verde 2     | 9/23/1997  | <a href="#">5291997005</a> |
| 1993 | Palo Verde 2     | 3/14/1993  | <a href="#">5291993001</a> |
| 1993 | Palo Verde 2     | 11/13/1992 | <a href="#">5291992006</a> |
| 1992 | Palo Verde 2     | 12/23/1991 | <a href="#">5291991008</a> |
| 1989 | Palo Verde 2     | 7/12/1989  | <a href="#">5291989009</a> |
| 1989 | Palo Verde 2     | 2/16/1989  | <a href="#">5291989003</a> |
| 1988 | Palo Verde 2     | 2/21/1988  | <a href="#">5291988005</a> |
| 1987 | Palo Verde 2     | 6/4/1987   | <a href="#">5291987010</a> |
| 1993 | Palo Verde 3     | 2/4/1993   | <a href="#">5301993001</a> |
| 1989 | Palo Verde 3     | 3/3/1989   | <a href="#">5301989001</a> |
| 1999 | Point Beach 1    | 5/14/1999  | <a href="#">2661999005</a> |
| 1996 | Point Beach 1    | 4/5/1996   | <a href="#">2661996001</a> |
| 1991 | Point Beach 1    | 6/29/1991  | <a href="#">2661991008</a> |
| 1988 | Point Beach 1    | 11/21/1987 | <a href="#">2661987005</a> |
| 1990 | Point Beach 2    | 10/27/1989 | <a href="#">3011989007</a> |
| 1988 | Point Beach 2    | 4/7/1988   | <a href="#">3011988001</a> |
| 1987 | Prairie Island 1 | 3/30/1987  | <a href="#">2821987004</a> |
| 1992 | Robinson 2       | 7/9/1992   | <a href="#">2611992014</a> |
| 1992 | Robinson 2       | 8/22/1992  | <a href="#">2611992017</a> |
| 1989 | Robinson 2       | 2/27/1989  | <a href="#">2611989004</a> |
| 1989 | Robinson 2       | 11/14/1988 | <a href="#">2611988026</a> |
| 1988 | Robinson 2       | 2/13/1988  | <a href="#">2611988005</a> |
| 1994 | Salem 1          | 4/7/1994   | <a href="#">2721994007</a> |
| 1991 | Salem 1          | 8/15/1991  | <a href="#">2721991027</a> |
| 1989 | Salem 1          | 6/9/1989   | <a href="#">2721989024</a> |
| 2002 | Salem 2          | 12/31/2001 | <a href="#">3112001008</a> |
| 1993 | Salem 2          | 4/15/1993  | <a href="#">3111993006</a> |
| 1991 | Salem 2          | 8/26/1991  | <a href="#">3111991012</a> |

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1990 | Salem 2          | 5/1/1990   | <a href="#">3111990017</a> |
| 1990 | Salem 2          | 9/22/1990  | <a href="#">3111990037</a> |
| 1989 | Salem 2          | 3/12/1989  | <a href="#">3111989005</a> |
| 1988 | Salem 2          | 6/22/1988  | <a href="#">3111988014</a> |
| 1991 | San Onofre 2     | 11/20/1990 | <a href="#">3611990014</a> |
| 1989 | San Onofre 3     | 1/6/1989   | <a href="#">3621989001</a> |
| 1988 | San Onofre 3     | 2/19/1988  | <a href="#">3621988002</a> |
| 1987 | San Onofre 3     | 6/21/1987  | <a href="#">3621987011</a> |
| 1994 | Seabrook         | 1/25/1994  | <a href="#">4431994001</a> |
| 1991 | Seabrook         | 9/27/1991  | <a href="#">4431991012</a> |
| 1998 | Sequoyah 1       | 5/19/1998  | <a href="#">3271998001</a> |
| 1992 | Sequoyah 1       | 4/29/1992  | <a href="#">3271992011</a> |
| 1992 | Sequoyah 1       | 8/31/1992  | <a href="#">3271992017</a> |
| 1988 | Sequoyah 1       | 3/24/1988  | <a href="#">3271988016</a> |
| 2000 | Sequoyah 2       | 1/18/2000  | <a href="#">3282000001</a> |
| 1992 | Sequoyah 2       | 8/21/1992  | <a href="#">3281992011</a> |
| 2001 | South Texas 1    | 12/16/2000 | <a href="#">4982000007</a> |
| 1994 | South Texas 1    | 3/10/1994  | <a href="#">4981994011</a> |
| 1991 | South Texas 1    | 1/26/1991  | <a href="#">4981991002</a> |
| 1989 | South Texas 1    | 10/6/1988  | <a href="#">4981988059</a> |
| 1989 | South Texas 1    | 12/2/1988  | <a href="#">4981988018</a> |
| 1988 | South Texas 1    | 2/28/1988  | <a href="#">4981988022</a> |
| 1988 | South Texas 1    | 3/30/1988  | <a href="#">4981988026</a> |
| 1988 | South Texas 1    | 8/26/1988  | <a href="#">4981988049</a> |
| 1992 | South Texas 2    | 12/24/1991 | <a href="#">4991991010</a> |
| 1990 | South Texas 2    | 1/8/1990   | <a href="#">4991990001</a> |
| 1989 | South Texas 2    | 4/10/1989  | <a href="#">4991989011</a> |
| 1996 | St. Lucie 1      | 7/3/1996   | <a href="#">3351996008</a> |
| 1995 | St. Lucie 1      | 11/24/1994 | <a href="#">3351994010</a> |
| 1995 | St. Lucie 1      | 11/22/1994 | <a href="#">3351994009</a> |
| 1993 | St. Lucie 1      | 1/8/1993   | <a href="#">3351993001</a> |
| 1987 | St. Lucie 1      | 2/12/1987  | <a href="#">3351987003</a> |
| 1987 | St. Lucie 1      | 4/14/1987  | <a href="#">3351987010</a> |
| 1991 | St. Lucie 2      | 11/9/1990  | <a href="#">3891990004</a> |
| 1989 | Summer           | 12/11/1988 | <a href="#">3951988013</a> |
| 1988 | Summer           | 5/12/1988  | <a href="#">3951988006</a> |
| 2000 | Surry 1          | 10/9/1999  | <a href="#">2801999007</a> |
| 1998 | Surry 1          | 10/11/1997 | <a href="#">2801997008</a> |
| 1993 | Surry 1          | 1/8/1993   | <a href="#">2801993001</a> |
| 1991 | Surry 1          | 12/3/1990  | <a href="#">2801990018</a> |
| 1989 | Surry 1          | 2/8/1989   | <a href="#">2801989006</a> |
| 1988 | Surry 1          | 8/15/1988  | <a href="#">2801988029</a> |
| 1987 | Surry 1          | 9/1/1987   | <a href="#">2801987023</a> |
| 1987 | Surry 1          | 9/20/1987  | <a href="#">2801987024</a> |
| 1991 | Surry 2          | 8/2/1991   | <a href="#">2811991007</a> |
| 1988 | Surry 2          | 3/27/1988  | <a href="#">2811988004</a> |
| 1988 | Surry 2          | 5/16/1988  | <a href="#">2811988010</a> |
| 1990 | Three Mile Isl 1 | 10/30/1989 | <a href="#">2891989001</a> |
| 1990 | Three Mile Isl 1 | 7/2/1990   | <a href="#">2891990006</a> |
| 1996 | Turkey Point 3   | 3/29/1996  | <a href="#">2501996007</a> |
| 1994 | Turkey Point 3   | 5/5/1994   | <a href="#">2501994002</a> |
| 1990 | Turkey Point 3   | 4/15/1990  | <a href="#">2501990008</a> |
| 1989 | Turkey Point 3   | 6/17/1989  | <a href="#">2501989011</a> |

| FY   | Plant          | Date       | LER                        |
|------|----------------|------------|----------------------------|
| 1987 | Turkey Point 3 | 5/27/1987  | <a href="#">2501987016</a> |
| 1987 | Turkey Point 3 | 7/1/1987   | <a href="#">2501987021</a> |
| 1987 | Turkey Point 3 | 9/13/1987  | <a href="#">2501987023</a> |
| 2001 | Turkey Point 4 | 10/21/2000 | <a href="#">2512000004</a> |
| 1992 | Turkey Point 4 | 3/26/1992  | <a href="#">2511992004</a> |
| 1989 | Turkey Point 4 | 4/12/1989  | <a href="#">2511989002</a> |
| 1989 | Turkey Point 4 | 9/15/1989  | <a href="#">2511989011</a> |
| 1994 | Vogtle 1       | 2/2/1994   | <a href="#">4241994001</a> |
| 1993 | Vogtle 1       | 4/18/1993  | <a href="#">4241993006</a> |
| 1989 | Vogtle 1       | 10/16/1988 | <a href="#">4241988028</a> |
| 1992 | Vogtle 2       | 4/23/1992  | <a href="#">4251992004</a> |
| 1991 | Vogtle 2       | 8/13/1991  | <a href="#">4251991009</a> |
| 1989 | Vogtle 2       | 3/18/1989  | <a href="#">4251989006</a> |
| 1993 | Waterford 3    | 10/2/1992  | <a href="#">3821992012</a> |
| 1992 | Waterford 3    | 11/17/1991 | <a href="#">3821991022</a> |
| 1991 | Waterford 3    | 8/25/1991  | <a href="#">3821991019</a> |
| 1990 | Waterford 3    | 12/23/1989 | <a href="#">3821989024</a> |
| 2002 | Wolf Creek     | 9/9/2002   | <a href="#">4822002005</a> |
| 1999 | Wolf Creek     | 5/12/1999  | <a href="#">4821999005</a> |
| 1993 | Wolf Creek     | 5/4/1993   | <a href="#">4821993009</a> |
| 1991 | Wolf Creek     | 10/23/1990 | <a href="#">4821990023</a> |
| 1987 | Wolf Creek     | 1/8/1987   | <a href="#">4821987002</a> |
| 1996 | Zion 1         | 11/12/1995 | <a href="#">2951995022</a> |
| 1993 | Zion 1         | 10/8/1992  | <a href="#">2951992019</a> |
| 1992 | Zion 1         | 11/7/1991  | <a href="#">2951991016</a> |
| 1991 | Zion 1         | 5/10/1991  | <a href="#">2951991008</a> |
| 1987 | Zion 1         | 4/30/1987  | <a href="#">2951987009</a> |
| 1998 | Zion 2         | 12/2/1997  | <a href="#">3041997009</a> |
| 1989 | Zion 2         | 12/11/1988 | <a href="#">3041988012</a> |
| 1987 | Zion 2         | 7/29/1987  | <a href="#">3041987006</a> |

**Table 11. LER listing for failure trend figure.**

**Figure 6**

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1992 | Calvert Cliffs 1 | 11/26/1991 | <a href="#">3171991009</a> |
| 1990 | Catawba 1        | 11/20/1989 | <a href="#">4131989027</a> |
| 1989 | Catawba 2        | 5/13/1989  | <a href="#">4141989011</a> |
| 1995 | Cook 1           | 9/12/1995  | <a href="#">3151995011</a> |
| 1992 | Crystal River 3  | 12/8/1991  | <a href="#">3021991018</a> |
| 1992 | Diablo Canyon 1  | 6/2/1992   | <a href="#">2751992010</a> |
| 1988 | Ginna            | 12/23/1987 | <a href="#">2441987008</a> |
| 1989 | Ginna            | 5/18/1989  | <a href="#">2441989003</a> |
| 1990 | Haddam Neck      | 8/2/1990   | <a href="#">2131990012</a> |
| 1998 | Indian Point 2   | 10/31/1997 | <a href="#">2471997024</a> |
| 1995 | Keweenaw         | 4/20/1995  | <a href="#">3051995006</a> |
| 1996 | Maine Yankee     | 8/17/1996  | <a href="#">3091996020</a> |
| 1988 | McGuire 1        | 8/12/1988  | <a href="#">3691988020</a> |
| 1991 | North Anna 1     | 11/1/1990  | <a href="#">3381990011</a> |
| 1997 | North Anna 1     | 10/3/1996  | <a href="#">3381996006</a> |
| 1997 | Oconee 3         | 5/3/1997   | <a href="#">2871997003</a> |
| 1997 | Palisades        | 2/21/1997  | <a href="#">2551997004</a> |

| FY   | Plant            | Date       | LER                        |
|------|------------------|------------|----------------------------|
| 1996 | Palisades        | 7/17/1996  | <a href="#">2551996010</a> |
| 1989 | Palisades        | 6/2/1989   | <a href="#">2551989010</a> |
| 1988 | Palo Verde 2     | 2/21/1988  | <a href="#">5291988005</a> |
| 2002 | Point Beach 2    | 2/22/2002  | <a href="#">3012002001</a> |
| 1987 | Prairie Island 1 | 6/18/1987  | <a href="#">2821987009</a> |
| 1994 | Salem 2          | 9/22/1994  | <a href="#">3111994010</a> |
| 1988 | Salem 2          | 6/18/1988  | <a href="#">3111988012</a> |
| 1999 | Sequoyah 1       | 4/15/1999  | <a href="#">3271999001</a> |
| 1991 | Sequoyah 1       | 2/18/1991  | <a href="#">3271991003</a> |
| 1992 | Sequoyah 1       | 8/10/1992  | <a href="#">3271992014</a> |
| 1988 | Sequoyah 2       | 2/12/1988  | <a href="#">3281988005</a> |
| 1994 | Sequoyah 2       | 1/8/1994   | <a href="#">3281994002</a> |
| 1990 | Sequoyah 2       | 8/22/1990  | <a href="#">3281990012</a> |
| 1992 | South Texas 2    | 12/24/1991 | <a href="#">4991991010</a> |
| 1987 | Surry 2          | 3/12/1987  | <a href="#">2811987001</a> |
| 1994 | Turkey Point 3   | 5/5/1994   | <a href="#">2501994002</a> |

## **5 DESIGN-CLASSES**

Differences within a design class due to system configuration were categorized first by number of steam generators (SGs) (which correlates to cold legs) and then by number of HPI pump trains. [Table 12](#) shows individual plant configurations and the design class they have been assigned.

**Table 12. Listing of the HPI design classes, Units associated with each design class, the number and type of HPI trains, the number of cold-legs, and the success criterion for a small LOCA (as stated in the IPEs).**

| HPI Class | Plant                  | Centrifugal Charging Pumps (CCP)   | Intermediate Head Safety Injection Pumps (IHSI)                         | Total High-Pressure Motor Trains | IHSI and CCP for ES Auto or Immediate Manual Start | Cold Leg Injection Paths | Steam Generators | Small LOCA success for HPI (injection phase)  |
|-----------|------------------------|--|---|----------------------------------|--|--------------------------|------------------|---|
| 1         | Arkansas Nuclear One 2 | —  | 3 (1 swing pump never operates unless one of the two is in maintenance) | 3                                | 2  | 4                        | 2                | 1/3 pumps; 2/4 injection paths  |
| 1         | Calvert Cliffs 1 & 2   | —  | 3 (backup pump requires operator)                                       | 3                                | 2  | 4                        | 2                | 1/2 pumps to 2/4 injection paths;   |
| 1         | Davis-Besse            | —  | 2   | 2                                | 2  | 4                        | 2                | 1/2 HPI pumps and flow to associated R/X nozzle   |
| 1         | Keweenaw               | —  | 2   | 2                                | 2  | 2                        | 2                | 1/2 HPIs to 1/2 cold legs, also allow for manual start of comp that didn't auto start                         |
| 1         | Palisades              | —  | 2   | 2                                | 2  | 4                        | 2                | 1/2 HPIs to 1/3 intact headers; assume SBLOCA fails fourth header   |
| 1         | Palo Verde 1, 2, & 3   | —  | 2   | 2                                | 2  | 4                        | 2                | 1/2 HPIs to 3/6 injection headers that feed the 3 RCS SI cold legs; SBLOCA assumed to fault one cold leg path |
| 1         | Point Beach 1 & 2      | —  | 2   | 2                                | 2  | 2                        | 2                | 1/2 HPIs to the unfaulted loop initially takes suction from BAST then auto switch to RWST                     |
| 1         | Prairie Island 1 & 2   | —  | 2   | 2                                | 2  | 2                        | 2                | 1/2 HPIs to 1/2 cold legs   |
| 1         | San Onofre 1, 2, & 3   | —  | 3 (one requires operator to manual realign)                             | 3                                | 2  | 4                        | 2                | 1/3 HPIs to 2/4 cold legs   |
| 1         | St. Lucie 1 & 2        | —  | 2   | 2                                | 2  | 4                        | 2                | 1/2 HPIs to 1/4 cold legs   |
| 1         | Waterford 3            | —  | 3 (one needs operator; installed spare)                                 | 3                                | 2  | 4                        | 2                | 1/2 HPIs to 2 intact cold leg injection paths   |
| 2         | Arkansas Nuclear One 1 | 3 (1 pump running; 1 swing pump never operates unless one of the two is in | —   | 3                                | 2  | 4                        | 2                | 1/3 pumps; 2/4 injection paths; the swing pump has to be manually aligned to EDG and SW                       |

| HPI Class | Plant                  | Centrifugal Charging Pumps (CCP)                 | Intermediate Head Safety Injection Pumps (IHISI) | Total High-Pressure Motor Trains | IHSI and CCP for ES Auto or Immediate Manual Start | Cold Leg Injection Paths | Steam Generators | Small LOCA success for HPI (injection phase)  |
|-----------|------------------------|--|--|----------------------------------|--|--------------------------|------------------|---|
|           |                        | maintenance)                                     |  |                                  |  |                          |                  |   |
| 2         | Crystal River 3        | 3 (1 pump running)                               | —  | 3                                | 3  | 4                        | 2                | 1/3 MUPs to 1/4 injection paths   |
| 2         | Fort Calhoun           | —  | 3  | 3                                | 3  | 4                        | 2                | 1/3 HPI to 2/4 legs   |
| 2         | Ginna                  | —  | 3  | 3                                | 3  | 2                        | 2                | 1/3 HPI to 1/2 legs   |
| 2         | Oconee 1, 2, & 3       | 3 (1 pump running)                               | —  | 3                                | 3  | 4                        | 2                | 1/3 HPIs to 1/4 RCS injection nozzles   |
| 2         | Three Mile Island 1& 2 | 3 (1 pump running)                               | —  | 3                                | 3  | 4                        | 2                | 1/3 HPIs through 1/4 injection paths  |
| 3         | Beaver Valley 1 & 2    | 3 (1 pump spare)                                 | —  | 3                                | 2  | 3                        | 3                | 1/3 Charging/HHSI pumps to 3/3 cold legs; model as 1/2CCPs to 3/3 cold legs since spare pump is unpowered                                       |
| 3         | Farley 1 & 2           | 3 (serves as HPI; one requires operator)         | —  | 3                                | 2  | 3                        | 3                | 1/2 HPI pumps to 2/3 cold legs for 4 hours; 1 normally operating, 1 in standby, 1 as backup to be aligned if one of the others is not available |
| 3         | H.B. Robinson          | —  | 3 (1 pump breaker is racked out)                 | 2                                | 2  | 3                        | 3                | 1/2 HPIs; 1 HPI pump is at time of IPE undergoing major overhaul hence disabled.  |
| 3         | Maine Yankee           | 3 (1 pump run, 1 pump standby, 1 pump spare)     | —  | 3                                | 2  | 3                        | 3                | 1/2 HPSI trains to 1/2 intact cold water loops from RWST; no credit for spare   |
| 3         | North Anna 1 & 2       | 3 (1 pump running; 1 needs operator)             | —  | 3                                | 2  | 3                        | 3                | 1/3 HHIs; model as 1/2 HHIs since third pump needs manual alignment   |
| 3         | Shearon Harris 1       | 3 (1 pump running; 1 pump spare)                 | —  | 3                                | 2  | 3                        | 3                | 1/2 HPIs *(one normally operating; have a spare pump that can be available in 8 hours)  |
| 3         | Summer 1               | 3 (1 pump running; 1 pump breaker is racked out) | —  | 3                                | 2  | 3                        | 3                | 1/2 HPSIs to 2/3 cold legs  |

| HPI Class | Plant               | Centrifugal Charging Pumps (CCP)     | Intermediate Head Safety Injection Pumps (IHSI)     | Total High-Pressure Motor Trains | IHSI and CCP for ES Auto or Immediate Manual Start | Cold Leg Injection Paths | Steam Generators | Small LOCA success for HPI (injection phase)  |
|-----------|---------------------|--------------------------------------|---|----------------------------------|--|--------------------------|------------------|---|
|           |                     |                                      |   |                                  |  |                          |                  |   |
| 3         | Surry 1 & 2         | 3 (1 pump is in "pull-to -lock")     | —   | 3                                | 2  | 3                        | 3                | 1/3 HHSIs to 1/3 cold legs; HHISI limited to simultaneous operation of 2 of 3 HHISI pumps             |
| 4         | Turkey Point 3 & 4  | —                                    | 4 (2 per unit)                                      | 4 (2 per unit)                   | 2  | 3                        | 3                | 2/4 HHISI trains to 1/3 cold legs; taking credit for other units pumps                                |
| 5         | Indian Point 2      | —                                    | 3   | 3                                | 3  | 4                        | 4                | 1/3 HPIs to 1/4 cold legs   |
| 5         | Indian Point 3      | —                                    | 3   | 3                                | 3  | 8                        | 4                | 1/3 HPIs to 1/4 cold legs   |
| 5         | South Texas 1 & 2   | —                                    | 3   | 3                                | 3  | 3                        | 4                | 1/3 HPSIs to 1/3 cold legs  |
| 6         | Braidwood 1&2       | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 CC or SI pumps to 2/4 injection paths   |
| 6         | Byron 1 & 2         | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 CC or SI pumps to 2/4 injection paths   |
| 6         | Callaway            | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 CC or SI pumps to 2/4 injection paths   |
| 6         | Catawba 1 & 2       | 2 (1 pump running)                   | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 NI or NV pumps to 2/4 injection paths   |
| 6         | Comanche Peak 1 & 2 | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 pumps to 2/4 injection paths  |
| 6         | Cook 1 & 2          | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/2 CCPs AND 1/2 SI pumps to 1/3 intact loops   |
| 6         | Diablo Canyon 1 & 2 | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 CCPs or SI pumps to 1/4 RCS cold legs   |
| 6         | Haddam Neck         | 2                                    | 2   | 4                                | 4  | 5                        | 4                | (1/2 HPIs to 3 of 3 unfaulted legs OR 2/2 HPIs to 2 of 3 unfaulted legs) AND 1/2 CCPs to # 2 cold leg |
| 6         | McGuire 1 & 2       | 2 (1 pump running)                   | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 CC or SI pumps to 2/4 injection paths   |
| 6         | Millstone 2         | —                                    | 3 (one pump is a swing pump that requires operator) | 5                                | 4  | 8; 4per sys              | 4                | 1/3 HPIs to 3 of 3 unfaulted loops OR 2/3 HPI supplying 2/3 unfaulted loops                           |
| 6         | Millstone 3         | 3 (1 pump running, 1 needs operator) | 2   | 5                                | 4  | 8; 4per sys              | 4                | 1/4 HPIs to 3/3 unfaulted RCS cold legs   |
| 6         | Salem 1 & 2         | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 centrifugal charging or SJS pumps   |
| 6         | Seabrook            | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 HPI trains (SI or CVCS) to 2/4 cold legs  |
| 6         | Sequoayah 1 & 2     | 2                                    | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 HPI trains (SI or CVCS) to 2/4 cold legs  |

| HPI Class | Plant        | Centrifugal Charging Pumps (CCP) | Intermediate Head Safety Injection Pumps (IHSI) | Total High-Pressure Motor Trains | IHSI and CCP for ES Auto or Immediate Manual Start | Cold Leg Injection Paths | Steam Generators | Small LOCA success for HPI (injection phase)   |
|-----------|--------------|----------------------------------|---|----------------------------------|--|--------------------------|------------------|--|
|           |              |                                  |   |                                  |  |                          |                  |  |
| 6         | Vogtle 1 & 2 | 2 (1 pump running)               | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/2 CCPs through 3/4 cold legs for 3 hrs. OR 1/2 SIs through 3/4 cold legs for 6 hours |
| 6         | Watts Bar    | 2                                | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 HPS is to 3/4 cold legs  |
| 6         | Wolf Creek   | 2                                | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1/4 HPS is to 3/4 cold legs  |
| 6         | Zion 1 & 2   | 2 (1 pump running)               | 2   | 4                                | 4  | 8; 4per sys              | 4                | 1 CCP (high-pressure) or 1 SIP (medium pressure)                                       |